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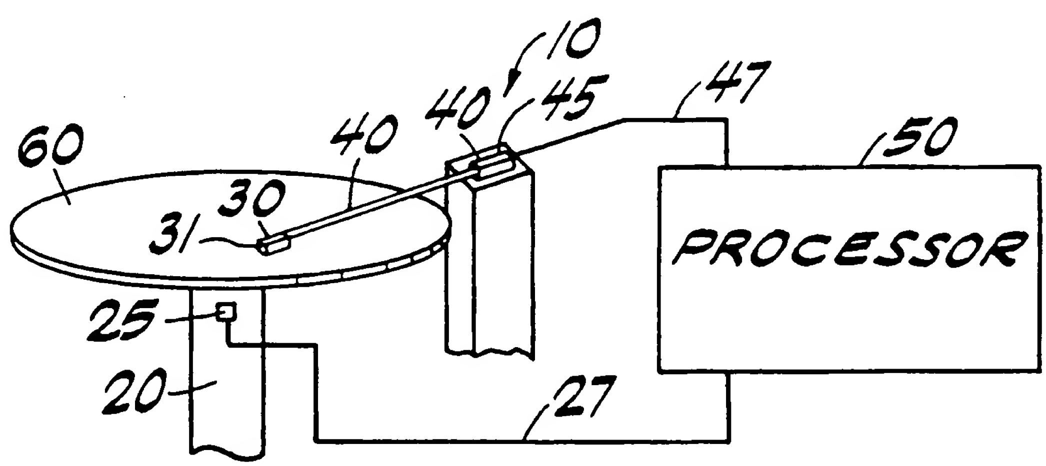

(57) Abstract

A patterned semiconductor wafer (60) is centered on a vacuum chuck (20) that is capable of being rapidly rotated about an axis normal to the wafer (60) surface. The vacuum holds the wafer (60) flat to the chuck (20). As the chuck (20) is rotated, the wafer (60) rotates and the surface of the wafer (60) is scanned (10) with an optical head (30). The output is fed through a signal line (47) of the read head (30) and is compared to a reference file in a processor (50) or signal representing what a perfectly pattern wafer should look like. Differences between the reference standard and the patterned wafer (60) indicate flaws in the patterning. In the case of an unpatterned surface such as a wafer, glass substrate for a liquid crystal display, or a magnetic memory, the reference signal is a null signal and any signal from the read head (30) would signify a flaw in the unpatterned surface.

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METHOD OF SCANNING SEMICONDUCTOR WAFERS TO INSPECT FOR DEFECTS

BACKGROUND OF THE INVENTION

Semiconductor wafers must be scanned for defects both before any patterning is done and after patterning to identify sites with defects that would lead to a bad semiconductor device when the wafer is cut into chips. As semiconductor wafers become larger and pattern features become smaller, the problem of scanning becomes more difficult as the 4th power of the wafer diameter. Methods or strategies for improved scanning for defects thus become increasingly important in keeping the cost of inspection in line with the cost of patterning the wafers in the first place. In addition, rapid scanning of wafers and similar devices makes in-process scanning and process control a reality. The present invention is a systems approach to scanning wafers that makes use of several existing technologies that are used together in a unique way.

SUMMARY OF THE INVENTION

A semiconductor wafer is centered on a vacuum chuck that is capable of being rapidly rotated about an axis normal to the wafer surface. Once the vacuum holds the wafer flat to the chuck, the chuck is rotated and the surface scanned with an optical head that is the same as that used to scan compact disks (CD's). The output of the read head is compared to a "golden standard" of what a perfectly patterned wafer should look like. Differences between the golden standard and the patterned wafer indicate flaws in the patterning. (In the case of an unpatterned wafer, the standard would show no signal

and any signal from the read head would signify a flaw in the virgin wafer).

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates the scanning apparatus of the present invention.

Fig. 2 depicts the scanning apparatus of Fig. 1 incorporating a plurality of read heads.

DETAILED DESCRIPTION OF THE DRAWINGS

The scanning apparatus 10 of the present invention is depicted in Fig. 1. The apparatus includes a rotating vacuum chuck 20, an optical read head 30, a read head actuator and arm 40 and a processor 50. Mounted to vacuum chuck 20 is a planar device 60 which is to scan and evaluate by scanning apparatus 10. In a preferred embodiment, planar device 60 is a semiconductor wafer containing a plurality of semiconductor devices.

The vacuum is supplied to the vacuum chuck 20 through a commercially available rotary coupling. The vacuum chuck 20 is necessary because semiconductor wafers 60 are out of flat in the free state to a degree sufficient to prevent rapid scanning. Even so, there is sufficient unevenness in the wafer surface 60 to require use of an automatic focus sensor 31 built into the CD read head 30. This sensor would cause the read head to be correctly positioned above the wafer using active feedback to an actuator thus keeping the read head in best focus at all times during the scanning.

As the patterning on the wafer 60 passes under the read head 30, variations in the materials of the pattern will cause the amount of reflected light from the wafer 60 surface to vary and this variation will be

detected by the read head 30. The output signal from the read head 30 is output on signal line 47 to processor 50 where it is compared with the golden standard. The rotating vacuum chuck 20 and the golden standard will be synchronized using a rotary encoder 25 on the rotating chuck 20. The output of rotary encoder 25 is input to processor 50 via signal line 27. The radial location of the CD read head 30 will be ascertained using a displacement or angular encoder 45 incorporated into the actuator 40. The combination of the rotary encoder 25 and lateral position encoder 45 permit the location on the surface 60 to be matched with the golden standard. This comparison between read head signal and golden standard would be made continuously by processor 50 as the read head 30 scans the wafer 60 from center to edge while the wafer rotates.

Another means for obtaining synchronization is to scan or image the flats and notches on semiconductor wafers 60 and correlating the position of the flats with the azimuthal or rotary encoder 25 reading. This then would be synchronized with the golden standard to ensure the patterning was correctly positioned relative to the flats and notches.

While the wafer 60 is preferably well centered on the vacuum chuck 20, there will inevitably be small residual decanters. Since the pattern coincident with the axis of rotation will remain fixed as the chuck 20 rotates, there is a means of locating the read head 30 with the axis of rotation to the limit of lateral resolution of the read head 30. As the read head 30 is scanned outward from the center of the wafer 60, the amount of information to be compared with the golden standard is small. In this time period of scanning near

the center of wafer 60, the residual decanter can be determined and the golden standard corrected to account for the once per revolution decentration or the lateral motion of the read head 30 actively controlled to match the noted residual decanter.

Because the wafer 60 is scanned in a spiral manner just as a phonograph record or the CD, from center to edge, there will be a much higher rate of scanned information at the edge of the wafer 60 than the center. The following are two methods of dealing with this problem. First, the wafer 60 is rotated at its fastest possible speed when it is being scanned near the center and slowed as scanning proceeds to the edge. Second, as depicted in Fig. 2, multiple read heads 30, 30', 30'' can be used, each on their own lateral position actuator 40, 40', 40''. Near the center, there would only be room for one read head 30 without interference. However, as the first read head 30 moves perhaps 20% of the way out from the center, a second read head 30' is moved in and scans in an interlaced manner with respect to the first read head 30. As the heads 30, 30' move farther out, subsequent heads 30'' would be brought in to scan in parallel with the first two, etc.

The present invention is not limited to the scanning of semiconductor wafers. The method and apparatus have similar applicability to unpatterned wafers and other nominally featureless, near planar surfaces such as computer hard drives, flat panel displays and the glass substrates for LCD screens and the like. Any large area, flat, patterned surface could equally well be scanned by the approach of the present invention.

In addition, because the scanning process is rapid, the method can be used for in-process scanning and the results of the scanning used for process control. The scanning can be accomplished fast enough to permit near real time adjustment of patterning parameters to improve yields and correct defects.

Another use of the process is to image the patterned wafer 60 or similar surface. By recording the output of the CD optical head 30 rather than just comparing it to the golden standard, a record can be produced of the surface 60 scanned. This image can then be used for diagnostic or other engineering purposes.

A preferred embodiment of the method of the present invention is for rapidly scanning semiconductor wafers 60 using a spiral scan such as is used on a phonograph or CD player. The method is faster than a raster scan because there is no starting and stopping of the motion. The method of the present invention can be used in connection with the following:

The use of a rotating vacuum chuck 30 to hold the semiconductor wafer 60 flat during scanning.

The use of a CD player type read head 30 to scan the wafer 60.

The use of a CD player read head automatic focus sensor 31 to keep the read head 30 correctly positioned vertically above the wafer 60 to maintain best focus. The sensor 31 output would drive an actuator 40 to hold the read head 30 in the best focus position using closed loop feed back just as is done on CD players.

The use of a rotary encoder 25 on the spinning vacuum chuck to encode the azimuthal position of the semiconductor wafer 60 for the purposes of synchronization.

The use of a lateral position or angular encoder 40 to encode the radial position of the read head 30 for the purposes of synchronization.

The use of a golden standard for the comparison of the read head signal from the semiconductor wafer 60 to the standard. Differences in the two signify a defect in the wafer.

The use of variable rotary speed to even out the information variation from center to edge of the rotating wafer 60, running the speed faster when scanning near the center of the wafer 60.

The use of multiple read heads 30, $30'$, $30''$ to increase the speed at which a wafer 60 can be completely scanned for defects.

The use of the signal comparison at the center of the wafer 60 to detect small residual decentration of the wafer 60 from the axis of rotation of the vacuum chuck 20 and to correct for the residual decanter by modifying the golden standard appropriately or by controlling the lateral position of the read head 30 in synchronism with the chuck 20 rotation to remove the effect of the decanter.

The use of the variation in the material properties of the patterned wafer 60 to vary the reflected light into the CD player read head 30 and to use this signal as that to be compared by processor 50 with a synthetic but perfect "golden standard" signal of the ideal patterned wafer.

To use the same scheme to inspect unpatterned wafers 60 by using the absence of signal from the read head 30 to indicate no flaws in the wafer 60.

To use this same scheme for the inspection of flat panel displays of LCD screens and other similar flat, patterned surfaces.

To use the rapid scanning process to create images of the surfaces scanned by recording the results of the scan in a circular format to replicate the surface being scanned. The images would be exact replicas of the surface scanned.

The use of rapid rotary scanning to provide in-process feedback for use in process control and for the inspection of virgin wafers and flat surfaces to control polishing processes and contamination levels.

Although the present invention has been described in relation to a particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

What is claimed is:

1. An apparatus for optically scanning a near planar surface comprising:

a rotating vacuum chuck upon which the near planar surface is mounted;

a read head disposed next to the near planar surface and generating an output signal representing a condition of the near planar surface;

an actuator coupled to the read head and controlling the position of the read head relative to the near planar surface; and

a processor coupled to the read head, the processor comparing the output signal generated by the read head to a reference signal.

2. An apparatus as set forth in claim 1, wherein the near planar surface is a semiconductor wafer, wherein the reference signal represents a pattern which should be formed on the semiconductor wafer and wherein the comparison by the processor identifies defects in the semiconductor wafer.

3. An apparatus as set forth in claim 1, wherein the near planar surface is a magnetic memory, wherein the reference signal is a null signal and wherein the comparison by the processor identifies defects in the magnetic memory.

4. An apparatus as set forth in claim 1, wherein the near planar surface is a glass substrate for a Liquid Crystal Display (LCD), wherein the reference signal is a null signal and wherein the comparison by the processor identifies defects in the glass substrate.

5. An apparatus as set forth in claim 1, further comprising:

a first encoder disposed next to the rotating vacuum chuck and coupled to the processor, the first encoder generating a first encoder signal representative of a position of the near planar surface; and

a second encoder coupled to the actuator and coupled to the processor, the second encoder generating a second encoder signal representative of a position of the read head, wherein the processor compares the first and second encoder signals to synchronize the scanning of the near planar surface.

6. An apparatus as set forth in claim 1, further comprising:

at least one additional read head disposed next to the near planar surface and generating an additional output signal representing a condition of the near planar surface at a second location, the at least one additional read head being coupled to the processor; and

at least one additional actuator coupled to the at least one additional read head and controlling the position of the at least one additional read head relative to the near planar surface, wherein the processor compares the output signal generated by the read head and the additional output signal generated by the at least one additional read head to the reference signal.

7. An apparatus as recited in claim 1, further comprising:

an automatic focus sensor coupled to the read head and coupled to the actuator, the automatic focus sensor generating a control signal used by the actuator to automatically position the read head in a proper focus position.

8. A method for optically scanning a near planar surface comprising:

mounting the near planar surface to a vacuum chuck;

rotating the vacuum chuck;

optically scanning the near planar surface using a read head and generating an output signal representing a condition of the near planar surface;

controlling the position of the read head relative to the near planar surface with an actuator; and

comparing the output signal generated by the read head to a reference signal to identify defects in the near planar surface.

9. A method for optically scanning a near planar surface as set forth in claim 8, further comprising:

synchronizing the rotation of the vacuum chuck with the optical scanning of the near planar surface.

10. A method for optically scanning a near planar surface as set forth in claim 8, further comprising:

rotating the vacuum chuck at a faster rate when the read head is positioned near a center of the near planar surface, and rotating the vacuum chuck at a slower

rate when the read head is positioned near an edge of the near planar surface.

11. A method for optically scanning a near planar surface as set forth in claim 8, further comprising:

determining an amount by which the near planar surface is decentered on the vacuum chuck.

12. A method for optically scanning a near planar surface as set forth in claim 11, further comprising:

altering the reference signal to account for the determined amount of decentering.

13. A method for optically scanning a near planar surface as set forth in claim 11, further comprising:

controlling the position of the read head to account for the determined amount of decentering.

14. A method for optically scanning a near planar surface as set forth in claim 11, wherein the amount of decentering is determined by comparing the output signal generated by the read head to the reference signal.

15. A method for optically scanning a near planar surface as set forth in claim 8, wherein the near planar surface is unpatterned and the reference signal is a null signal.

16. A method for optically scanning a near planar surface as set forth in claim 15, wherein the near planar surface is a glass substrate for a Liquid Crystal Display (LCD).

17. A method for optically scanning a near planar surface as set forth in claim 15, wherein the near planar surface is a magnetic memory.

18. A method for optically scanning a semiconductor wafer comprising:

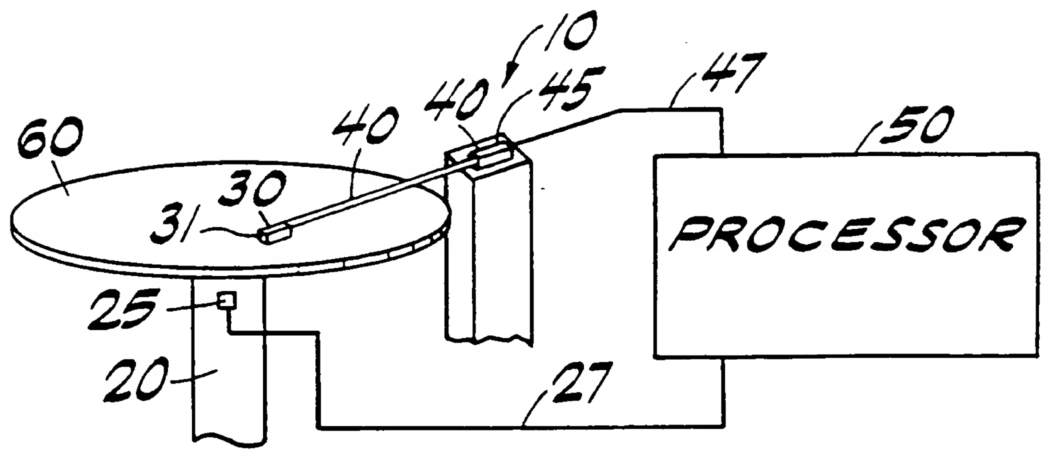
mounting the semiconductor wafer to a vacuum chuck;

rotating the vacuum chuck;

optically scanning the semiconductor wafer using a read head and generating an output signal representing a condition of the semiconductor wafer;

controlling the position of the read head relative to the semiconductor wafer with an actuator; and

comparing the output signal generated by the read head to a reference signal to identify defects in the semiconductor wafer.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47
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45
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60
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30
31
PROCESSOR
25
20
27

FIG. 1

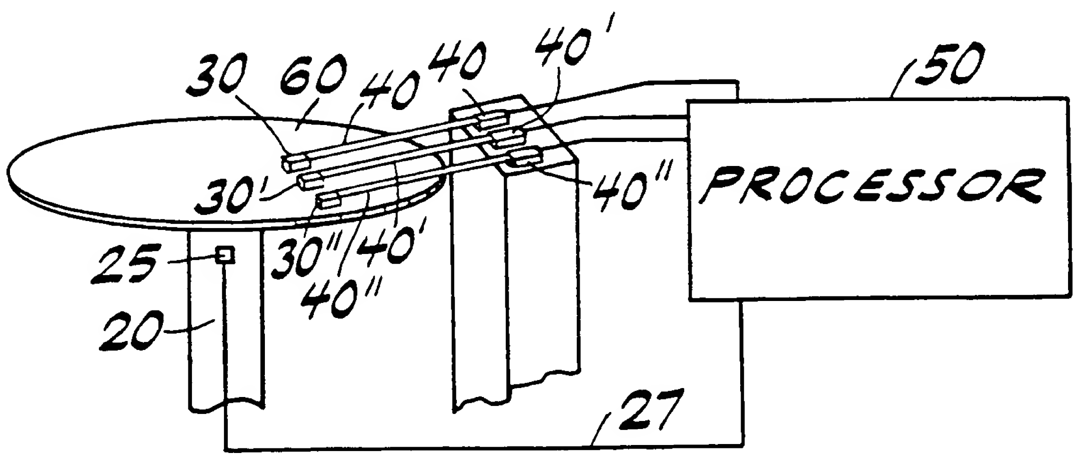
30
60
40
40
40'
50
PROCESSOR
30'
40''
25
30''
40'
40''
20
27

FIG 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/03239

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G01N 21/00, 21/84, 21/86; G01B 9/08, 11/00
US CL : 356/237-239, 426, 394; 250/559.39-559.49
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 356/237-239, 426, 394; 250/559.39-559.49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,938,654 A (SCHRAM) 03 July 1990 (03/07/90), see entire document.	1-18
A	US 4,402,613 A (DALY ET AL) 06 September 1983 (06/09/83), see whole document.	1-18
A	US 4,893,932 A (KNOLLENBERG) 16 January 1990 (16/01/90), see whole document.	1-18
A	US 5,189,481 A (JANN ET AL) 23 February 1993 (23/02/93), see whole document.	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
06 MAY 1998	23 JUN 1998

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/03239

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Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: defect, flaw, wafer, semiconductor, lcd, magnetic memory, encoder, scan, read head, actuator, predetermined, reference, threshold